



Ecosystem based Disaster Risk Reduction approaches (EbDRR) as a prerequisite for inclusive urban transformation of Nagpur City, India

Shalini Dhyani^{a,*}, Shruti Lahoti^b, Shubhankar Khare^a, Paras Pujari^a, Parikshit Verma^a

^a CSIR-National Environmental Engineering Research Institute, Nagpur 440020, Maharashtra, India

^b United Nations University, Institute for the Advanced Study of Sustainability (UNU-IAS), 5-53-70 Jingumae, Shibuya, Tokyo 150-8925, Japan

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ABSTRACT

Nagpur city is among the fastest growing agglomerations of Central India. The city is considered to be a fore-runner in sustainable development amidst the rapid urbanization occurring in India. Though, selected under the “smart city” project launched by the Indian government, the city faces many urban challenges ineffectively addressed by the current development plan. Haphazard and rapid infrastructural development without any comprehensive plan is leading to urban sprawl that compromises urban green infrastructure across the city. It excludes utilizing benefits of nature and ecosystem services to complement and reduce urban stress. This has led to wetland reductions, reduced water infiltration affecting the water table and causing water shortage, flash floods, significant loss of vegetation cover and biodiversity across the city and increased heat island effects. These issues along with current approach that discounts the importance of ecosystems-based approach has put forward many challenges and a question with regard to sustaining “green image of the city”. To reduce risk against uncertainties, it is imperative to understand human-environment connections that involves diverse values and ecosystem services provided by the natural environment of the cities. Present study is a review of major issues raised due to un-planned development and addresses the feasibility and appropriateness of using the EbDRR approach. Environmental engineering based approaches having potential to transform Nagpur City into to a “smart city” can set an example for other Indian cities to follow. This article facilitates understanding and practical applications of ecosystem based approaches and practices to counter negative impact of urbanization.

1. Introduction

Asia with 42% of its population residing in cities in 2010 is undergoing rapid urbanization where urban areas are estimated to contribute 80% of the region's GDP [1]. At a global scale, India contributes 14% of urban population [2] in five megacities with over 10 million population and by 2030 a rise to seven megacities [3]. In addition to the megacities India has 53 urban agglomerations with above 1 million as of 2011 *versus* 35 in 2001. The spatial expansion of the top 100 cities has proliferated by almost 2.5 times to more than 5000 km² [3,4]. The population grew at the rate of 17.6% from 2001 to 2011 with urban populations increasing by 32.8% by 2017 and is forecasted to be 33.9% and 47.8% by 2020 and 2050, respectively [5,6]. These urban centers have extraordinarily large ecological, carbon and water ‘footprints’

with complex, powerful, and often unforeseen effects on ecosystems.

As per government's vulnerability atlas 38 Indian cities are located in seismic susceptibility zones making them vulnerable [7]. Vulnerability associated with geo-climatic and socio-economic conditions make India the most disaster prone country in the world [7]. Haphazard and un-planned urbanization, lack of long term vision and comprehensive plan with poor urban governance are key underlying factors accelerating the risk against disasters in these urban areas [8]. This is evident through increased regularity and concentration of urban disasters witnessed by India in the last few decades. The increase is not just in term of number of event but increasing gravity as well as complexities that has provoked and enhanced the requirement of pre-disaster preparedness and mitigation efforts as a mandate for all Indian cities. High density urban regions are at greater risk from potential disasters

Abbreviations: ACCRN, Asian Cities Climate Change Resilience Network; AMRUT, Atal Mission for Rejuvenation and Urban Transformation; CCA, Climate change adaptation; CNC, City of Nagpur Corporation Act; CPCB, Central Pollution Control Board; CSIR, Council for Scientific and Industrial Research; Eba, Ecosystem based adaptation; EbDRR, Ecosystem based disaster risk reduction; ES, Ecosystems services; FLG, Landfill gas; GDP, Gross Domestic Product; GI, Green infrastructure; IGBC, Indian Green Building Certification; JNURM, Jawaharlal Nehru National Urban Renewal Mission; NbS, Nature based solution; MAHAGENCO, Maharashtra State Power Generation Co. Ltd.; MIHAN, Metro Rail Project, Industrial Park; MIDC, Maharashtra Industrial Corporation; MLD, million liters per day; NMC, Nagpur Municipal Corporation; NEERI, National Environmental Engineering Research Institute; SEZ, Special Economic Zone; TPD, Tonne per day; VNIT, Visvesvaraya National Institute of Technology

* Corresponding author.

E-mail addresses: shalini3006@gmail.com, s_dhyani@neeri.res.in (S. Dhyani).

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Fig. 1. Prominent Urban wetlands of Nagpur Gorewada, Futala, Ambazari and Kanhan River (Clockwise).

[8,9] thus, making Indian cities more vulnerable against climate-meteorological associated disasters with a toll rising to approximately 900 cities characterized by their high population density [10]. Enhancing resilience of cities against uncertainties is no more a choice or option but a prerequisite for all Indian cities.

Nagpur is third highly urbanized centre in state of Maharashtra after Mumbai and Thane while, about 42.4% (41 million) of the state population resides in 29 different urban agglomerates with 12 having more than 1 million population [11]. Rapid urbanization of the city has co-occurred with a reduction in size, fragmentation and degradation of green areas. Rise in population and urban sprawl are important factors increasing vulnerability and exposure of residents. Exponential rise in demography and increased immigration due to employment availability has led to high residential demand. This is due to poor and un-planned construction in formally open green spaces, illegal settlement along water and drainage courses, agriculture land conversions and increase in hard surfaces throughout the city. This has further increased issues like heat island effect due to less surface area available for infiltration and discharge, air pollution due to reduced green coverage etc. [12].

In the last few decades there has been increased acceptance and endorsement of the ecosystem approach as a predominant agenda to address environmental management dialogue. The evolution of a framework for ecosystem based approaches from scholastic academic discussions to applied natural resources conservation, restoration and management in urban landscapes and its contribution in framing effective policies is still in the making [8]. Urban and policy planners and decision makers in India are also understanding the importance of ecosystems' restoration and management. Under this purview study was designed under following objectives:

- Understanding the current environmental issues and future concerns of the city if infrastructural development continues in the similar pattern
- Understanding the integrated ecosystem based approaches to address emerging environmental issues
- Assessing the challenges by particularly considering options for developing exemplar smart cities initiatives.
- Understanding the urban planning and development considerations for integration of EbDRR approaches and their possible implications in shaping the built environment to transform urban landscapes.

The article also attempts to understand the importance of integrating resilience against climate led vulnerabilities (water shortage, heat islands etc) to adapt more readily to shocks and stresses. The study methodology adopts a combination of an extensive secondary literature review, research and field based observations carried out by authors from diverse discipline from August 2016 to June 2017 as primary data sources and data analysis to support the research. Remote sensing data was used to understand the decadal land use change in the cities buildup area and its impact on the open green and blue spaces (1990–2016). Additionally, opinions taken in 2017 of smart city experts from India and abroad in resilient urban planning and integrating environment related disciplines is included to corroborate the findings of the observations, primary data and secondary literature. The experts included representatives from diverse discipline including urban planners, landscape planners, researchers from scientific organizations, civil engineers, hydro-geologists and biodiversity experts who are actively involved in development and planning of the Nagpur city.

2. Nagpur fast-growing urban agglomerate

Nagpur is the thirteenth biggest urban agglomeration in India and the third biggest city in Maharashtra. Located in on the edge of central Deccan plateau of India, at a mean elevation of 310 m above msl covering 217.56 km². The city has hot, dry and tropical climate, where summer temperature rises to 48 °C making it hottest places across India while, in winter temperature dips to 10° to 12°C. The average annual rainfall is 1161.54 mm. The city is considered wetland rich district of Maharashtra as it contributes 4.12% to the state wetland area [13]. The city is in Seismic Zone-II as per the seismic zonation map of India with the Vainganga and Wardha river basins as earthquake-prone. In northeast corner of Maharashtra, the earthquake activities in Nagpur and Bhandara districts may be associated with Deolapar thrust or sheared and faulted zones of Ramtek and Sakoli Basins and it observes Earthquake intensity of VI MSK. Nagpur being girdled by breathtaking dense forest that engulfs most alluring flora and fauna has been heralded as the “Tiger Capital of India” [14]. The city enjoys the privilege of being termed as the richest and greenest city with latent potential and hub of health care industry in the state. Specked with natural as well as artificial lakes, the biggest lake in the city is Futala Lake (0.26 km²) while other small lakes are, Ambazari, Gandhisagar, Naik,

Lendi, Sonegaon, Telankhedi, Pardi, Khadan, Gorewada, Tilhara, Sakardara, Naik talab, Raghuji talab, Sukravari talab, Baradri talab and Dhobi talab (Fig. 1). The region falls in the drainage basins of Nag, Kanhan, Pohara and Pili river that transverse the city from west-to-east direction. The natural areas in city consists of water bodies, crop lands, fallow lands, wastelands, urban forests, campus forests, and parks. The land use patterns for the city shows 69% of area under development. Out of the total developed area, 45% is residential, 6% is under commercial and industrial use, 41% of land is under public use, while, 8% of land is under parks and gardens. Being one of the greenest cities of India city has 18% of its area under forests and plantations, 17% under cultivation and 2% under water bodies [14]. The city showcases many green pockets that are rich in biodiversity including plants, avifauna, macrofauna, mesofauna, mammal and reptile diversity. The population of Nagpur city accounts for 75% of the total population of district [15]. Preliminary estimate shows rise in urban population in Nagpur district from 64.26% in 2001 to 68.30% in 2011 [16,17]. There has been an increase of 1.1 million people in the past 5 years (2012–16). The size of disadvantaged population in the state is significant of which Nagpur has the second largest number (though, barely 7% of the total in the state).

3. Results

3.1. Emerging challenges in rapidly growing city of Nagpur

In the face of rapid urbanization, urban agglomerates in India, particularly in Nagpur, are transforming and making them unsafe and susceptible to increased climate variabilities and vulnerabilities. The changing lifestyles and the dilemma between growth vs. development are some of the common factors to aggravate this susceptibility. Increasing urbanization in Nagpur is changing the natural environment on the fringes of the city as well as inside the city premises. Expanding boundaries are encroaching natural buffers existing along the peripheries with increasing population density and development alongside these open space areas. The major environmental issues observed in the city are pollution of air, water, soil, decreasing green spaces and wetlands, reduction in water infiltration, ground water depletion, increased flash floods, and increased expansion and emergence of urban heat islands (Fig. 2). The broader picture of urbanization reflects its roots in largely uncontrolled process of land conversion. Lack of comprehensive land use planning is currently resulting in substantial loss and degradation of natural environment, decline in ecosystem services and massive damage to biodiversity [8]. Inefficient land-use planning and policies for infrastructure development have resulted in rigorous

concretisation in Nagpur. Being an economic centre with limited land resources, the developmental activities gets priority for land use over ecological usage leading to heavy exploitation of natural resources, land conversion, overcrowding and increasing inequalities and increased exposure to risks. Nagpur is presently undergoing rapid transformation with implementation of metro rail Project, industrial park (MIHAN) and Mumbai by expressway. Development of 11 Maharashtra Industrial Corporation (MIDC) in and around Nagpur with MIDC in Butibori is Asia's largest Industrial zone and industrial suburb for Nagpur. Multi-modal International Cargo Hub and Airport (MIHAN), International Airport and Special Economic Zone (SEZ) for healthcare development in city, processing units, maintenance, repair, and overhauling of aircraft, information technology park, and manufacturing units are making Nagpur a fast-growing urban agglomerate.

City development plan has estimated 73% of the areas to be under development by year 2031 [14]. In Nagpur about 51% (110.9 sq.km) of land is under residential and commercial use and with increased infrastructural development very few spaces are left in the city as green and natural. The land use conversion map as shown in Fig. 3 clearly reflects loss of vegetation and green cover in the last few decades due to expansion of the city. The urban sprawl has impacts on biodiversity and ecosystem services of the city as evident through Fig. 3. affecting the wellbeing of local people (e.g., polluted wetlands without vegetation buffers and build up areas without green spaces have severely affected future water dependency of the city) (Fig. 4). Though, conservation and management of resources is still to be effectively implemented, Nagpur Municipal Corporation (NMC) has claimed 21,43,838 trees within the city limits, amounting to 9871 trees per km² by 2012. Despite, the massive tree felling in recent years, the first comprehensive census has put the number of trees within city limits at 21,43,838 bringing almost 9 trees for every 10 persons [14]. It is a common to notice large felling of trees in the name of road broadening, putting electric lines and cables, and sometime even for electrification during festivals. Trees are either pruned ruthlessly or are cut down completely leading to loss of green spaces of the city at a very rapid pace.

Urban development is having selective policies at national and state level regarding industrial development and economic activities. Land-use change is transforming the landscape pattern and structure of the region, leading to fragmentation and loss of connectivity of green patches via green corridors and reduction in the native plant species and animals [18]. As per the City of Nagpur Corporation Act (CNC Act, 1948) [19], the major accountability of Nagpur Municipal Corporation (NMC) lies in providing Nagpur's citizens basic urban services which

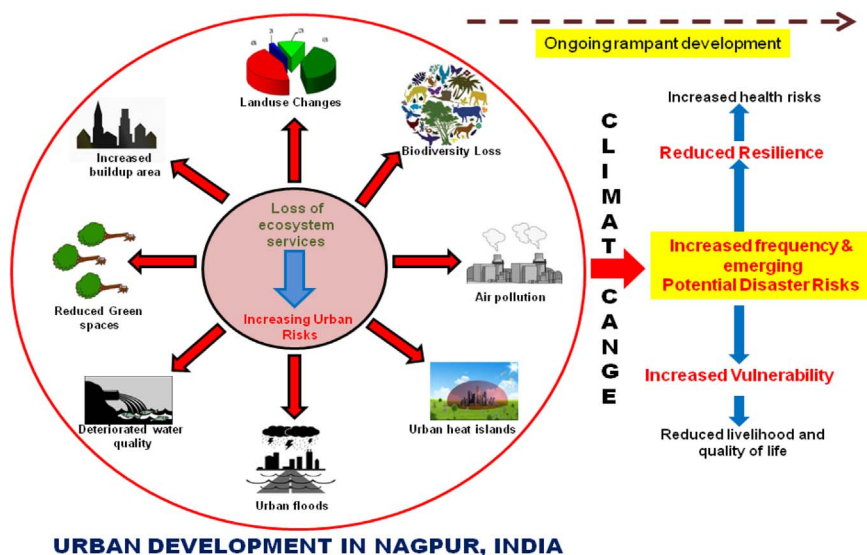


Fig. 2. Degradation of ecosystem services and consequences leading to increased frequency of urban risks and potential disasters (developed by authors).

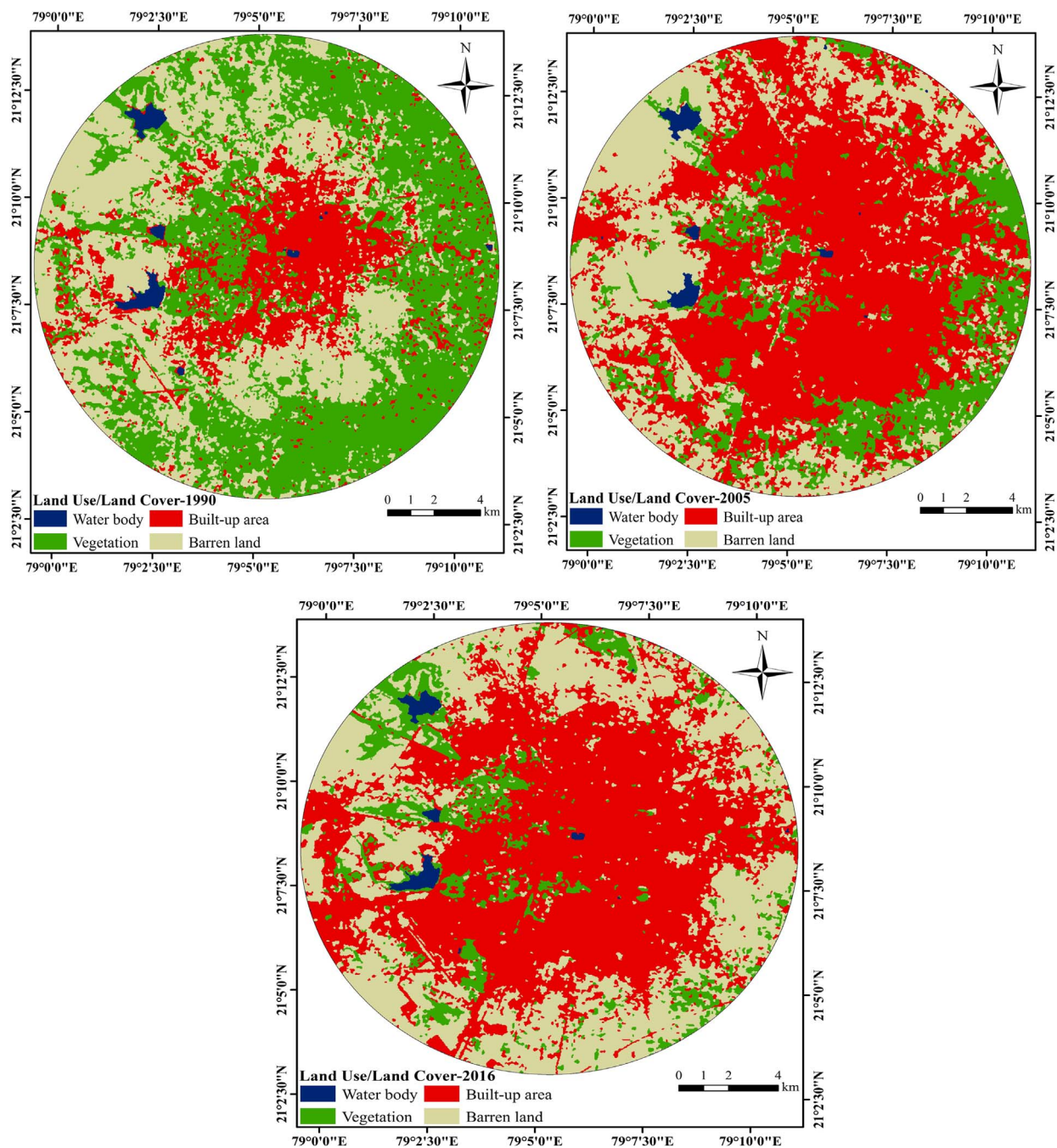


Fig. 3. LULUCC (1990–2016) leading to increased buildup area, barren lands and decreased vegetation cover (authors' own).

includes water supply, sewerage, waste management, slum improvement, transport infrastructure, parks and gardens, primary health care and education facilities. NMC co-ordinates with various other government organizations for delivering basic urban services from its 10 zonal offices. But increasing loss of vegetation, shrinking and polluted wetlands, depleting ground water resources, flash floods and handling solid waste of the city is a major challenge for NMC (Fig. 2). The nature of threats to fresh water resources is apparent and uniform across the city, though some of them may be site specific (Fig. 4). Identified environmental threats in the city vary in character and intensity while, the main causes are same viz. land use change, catchment area degradation, misuse of water usage, domestic and industrial pollution, eutrophication, and intrusion of exotic weeds. All of these have caused negative and cumulative environmental impacts and are incremental with time having long-term effects [13–15,22,23,26].

Water quality in wetlands and rivers have deteriorated due to continual discharge of domestic, industrial wastewater and other solid waste (Fig. 4). Nag river has dissolved oxygen levels routinely dropping to zero. At present, untreated and treated sewage is discharged to the Nag river while, the river water is used for growing vegetables and floriculture. The use of the treated sewage in growing vegetables is a matter of concern and has long-term implication for human health. All the lakes, near urban or residential areas, are polluted at different levels because of anthropogenic activities. These urban lakes had been important in maintaining the surface and ground water balance of the city and in protecting urban ecosystems apart from its uses for different purposes namely recreational, water supply, and fishing. These lakes were earlier source of water for domestic purpose however due to increased pollution now they are used for industrial purpose after treatment. Currently, about 410 MLD (million liters per day) of untreated



Fig. 4. Pertinent environmental concerns for Nagpur city sewage discharge in an urban water body (left), urban sprawl and solid waste haphazardly disposed (right).

wastewater is being disposed in Nag and Pili river [20]. Deterioration of lake water quality has led to public health problems with increased water borne diseases responsible for high human mortality and especially child mortality. These include gastro, diarrhea, cholera, typhoid, viral hepatitis, influenza A (H1N1) while, outbreak of dengue, malaria, leptospirosis and chikungunya have been very frequent in the last few decades and common every year. The domestic water demand of the city i.e. 560 MLD is met by three surface water sources namely Kanhan river, Pench project and Gorewada lake [15]. Present domestic wastewater treatment capacity by Nagpur Municipal corporation needs serious augmentation efforts. Water shortage during summer is severe due to depleting and unprotected ground water sources leading to significant loss in base flow and dependency on reservoir water stored for irrigation purpose of the surrounding villages. Reducing wetlands and biodiversity loss at large is accelerating the pace of water shortage while, the capacity of current water management infrastructure is insufficient to adapt to changing circumstances considering climate change impacts. There are 54 Major Dams (Height from foundation 10 m or more) in Nagpur District and the strategic management of water resources of these dams is based on a theoretical increase in population considering certain losses per year, however it does not considers climate change led variability in weather and vulnerabilities that might significantly affect the water resources [20]. The present water management approach to overcome water shortage of city during summer by diverting water stored for rural irrigation purpose also adversely affects increased drought incidences in rural Vidarbha region. Highest suicide rate among farmers in the region due to water unavailability in drought season to irrigate farms leading to crop failure, has been a matter of serious national concern for last few years. Another management level issue related to fishing rights, which was once a customary activity carried out by locals both individually and communally is now issued only *via* tenders, promoting commercial fishes for high economic gain but hampering diversity of local fish varieties.

Being flood-prone during monsoons (seismic zone II) and with seven major floods in the last 30 years, 13% of the city population lives in flood-prone areas [20]. The city lacks 100% underground drainage system and 100% sewage treatment facilities. Most of the drainage system of the city is very old and needs restoration. The increased immigration and population, upcoming infrastructural developments and construction activities is exerting tremendous pressure on existing drainage system. The required width of drains has also been reduced by informal and illegal settlements along the drainage and the natural water streams of the city. City receives significant rains during the monsoon that lasts from June end to Sep mid or end but most of it goes waste. Urban flash flooding in some areas of the city has been experienced quite frequently almost every year. During heavy rainfall there is higher runoff which increases the flood peaks from 1.8 to 8 times and flood volumes up to 6 times [20]. Increased accumulation of solid waste

and other garbage into drains also makes the task of maintaining them periodically difficult for the authorities [21,22,26].

One of the key challenges for the city is managing solid waste of the city that currently lacks segregation of waste at the source and absence of proper and sufficient transfer stations and landfill facilities. The waste management system in Nagpur is presently inadequate [21,22]. Open dumping, open burning, threats of environmental pollution, absence of landfill gas (FLG) monitoring facilities are the most important needs for the city. Irregular collection along with inadequate processing and disposal services have led to open dumping of enormous amount of waste, which has significant environmental and health impacts. The city produces 900–1000 TPD of waste, out of which only 150–200 TPD can be treated. Presently, NMC is treating only 22% of the sewage generated of the city. An additional 345 MLD treatment plant is proposed to be implemented which will be able to supplement the treatment facility which treats 100 MLD to 230 MLD [21]. The City's Bhandewadi dumping yard catches fire often and leads to critical health impact of residents, schools and hospitals. There is need of source segregation, optimized transport facilities, LFG monitoring, and improvement of plant processing capacity [22].

Decreasing vegetation cover and increasing development without due consideration for urban green spaces is leading to increased "urban heat islands". The location of the city on the Central Deccan Plateau makes the situation even worst during hot summers. Remote sensing studies [23] have shown higher temperatures in densely developed areas as compared to sparsely developed and vegetated areas. Continual development, constructions of cement-concrete roads, residential and commercial buildings are adding to the impervious surface in the city. It has given rise to increased heat islands in many places of the city *viz.* Sitabardi, Sadar, Mahal, Kamptee are to name a few. There is a need to map sites and gather relevant information on a range of heat risk factors including daytime and night time urban heat islands, impervious surfaces, urban tree canopy and cooling centers. The International Energy Agency (2008) [24] and the Stern Review (2006) [25] have already reflected upon urban role of agglomerates' in consuming 70% of the total global energy and more than 75% of the GHGs which significantly increase the severity of climate change and energy security [26]. Climate led variabilities and vulnerabilities are anticipated to only aggravate existing and emerging urban disaster risks for Nagpur that range from annual droughts, heat islands emergence and flash flooding during the monsoon season and continuously shrinking wetlands and ground water depletion.

3.2. Urban Development of Nagpur as a smart city

Natural resources and the environment (air, water, soil, wetlands, lakes, oceans, biodiversity, forests, wildlife, climate change *etc.*) are protected under different relevant acts and policies. Country has very

strong and well-drafted acts and policies in the world however, weak implementation and enforcement has stalled effective protection of the natural resources. Urban policies are linked to national and regional physical development plans that define the scope and scale of national infrastructure programmes. They also form basis of developing special industrial and economic areas along with housing and environmental improvement programmes. Jawaharlal Nehru National Urban Renewal Mission (JNURM) is one of the physical development plans and more recently, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) [27] has been linked to the ambitious smart cities development project. Smart cities mission is working to create models of sustainable urban growth across 100 satellite towns of the country. Nagpur city has also been shortlisted under 'Smart City Mission' by government of India [28]. AMRUT project, 2015 envisions to develop '100 smart cities', as satellite towns of larger cities of the country by modernizing these mid-sized but rapidly growing cities [29]. The smart city model has been argued to be a promising solution to fuel sustainable development and improve standard of health, comfort, and happiness experienced by urban dwellers of the country. Core idea of the project is to facilitate the aspirations, needs, and improve quality of life of urban residents, however the model ignores key elements of environmental sustainability [30]. As per smart cities guidelines issued by the ministry of urban development, the planners very well state that requirements of smart city may vary from state to state and city to city. These requirements are going to depend on the level of development, willingness to change and reform, resources and aspirations of the city residents. The core infrastructure elements mentioned for city development plan under AMRUT include adequate water supply, assured electricity supply, sanitation, including solid waste management, efficient urban mobility and public transport, affordable housing, especially for the poor, robust IT connectivity and digitalization, good governance, especially e-governance and citizen participation, sustainable environment, safety and security of citizens, particularly women, children and the elderly, along with facilities for health and opportunities for education [31].

Smart city development plan and policy document somewhere lack to address source of the round the clock energy and water supply. Document has a strong emphasis on technology driven solutions that include wi-fi networks, metro trains, sensors to monitor air pollution *etc* to meet technology, mobility and clean environment demands of growing population. Though, smart use of available and reducing land resources in urban areas by integrating urban greens spaces in growing urban infrastructure planning is missing. Vision to integrate and conserve remaining green islands by linking them through green corridors, protection and conservation of natural water bodies, restoring ecosystems and ecosystem services has not found any significant space in the proposal. From the introduction of green infrastructure, to the commitment and active participation of urban residents to promote urban greening, there are several ways in which the urban environment and integration of biodiversity needs to be promoted in urban planning. Cities supporting greening projects are likely benefitted through the value of ecosystem services for urban residents and also in providing them a soothing and stress free environment.

Guidelines, fleetingly mention disaster management, but no details or discussions on that. Disaster preparedness by using nature based solutions in the city is important and this will also help to achieve conservation goals. Healthy ecosystems support an array of ecosystem services and help to improve quality of life and human wellbeing [32]. By active people's participation city municipal corporation has initiated projects to rejuvenate and improve the conditions of natural lakes. Lake rejuvenation activity included removal of infringement on the banks of the lakes, desilting, water purification, landscaping and beautification of the lake [33]. Such efforts are required to be taken on a regular basis with proper monitoring plan by city managers and planning authorities. Management of urban flooding or flash flooding is a top priority for Nagpur city authorities. Smart city planners will require early warning

systems as natural incidences of drought, storm, flash floods have frequented in last few years. Processing solid waste management as the biggest challenge and efforts by city municipal corporation for Bhandewadi landfill site requires scientific and judicious planning keeping in mind that most of the landfill sites are working way beyond their life span. Optimistic recognition of the landfill sites by the government and ministry of urban development is a welcome step. There is vital need to address the issue of managing the solid waste of growing cities and future smart cities by using cost effective, long term but efficient ecosystem based approaches. Solid waste windrow were developed and stabilised at landfill site of Bhandewadi. These windrow were further treated chemically, to remove foul smell of waste, and were rapidly turned into compost. Though, frequent fires on landfill of Bhandewadi destroy many windrow in a regular manner hence, ecosystem based approach of stabilizing them before treating them chemically can help addressing the issue. Implementation of waste separation at points of collection (line screening) and separate collection of waste at source are first steps towards clean and smart city plan.

Nagpur city needs to recognize and integrate resilience as core agenda of smart city development along with Urban SDG 11 [34]. City of Surat Gujarat (one of the fastest growing ten cities of the world) being part of Asian Cities Climate Change Resilience Network (ACCRN) has set an official Resilience office and works on building Community of inclusive urban climate change resilience. This is a worthy example that needs to be endorsed and shared with smart city planners of the country. Urban planning can play a significant role in reducing the impacts of natural hazards for Nagpur city by increasing resilience and reducing vulnerability of people as well as infrastructure. Planning in terms of system resilience, efforts should focus on the potential of green infrastructure to allow adaptation and even transformation in the face of future challenges such as climate change, food insecurity, and limited resources. The linkage between urban planning and disaster mitigation is so far not evidently theorized [35,36] rather than reducing vulnerability the focus has been on hazard mitigation through technical solution and establishing grey structures [37]. Mitigation is essential to reduce the impact of hazard due to disasters and climate variability however, adaptation reduces the vulnerability of people against hazard. Understanding of climate change adaptation (CCA) is equally important to enhance resilience of people against disasters and climate risks. Vulnerability in this context is susceptibility of locals due to stress conditions (water shortage, heat islands *etc.*) and is determined by physical, social, economic, and environmental factors of the city [38]. The vulnerability of locals can be reduced by judicious urban planning by including ecosystem based approaches that have been so far ignored and not given required emphasis [39]. With the current challenges of urbanization, population explosion and sprawl development, urban planning needs to integrate resilience strategies and ecosystem based adaptation approaches to reduce the impact of future disasters [40] in the city. By enforced policy framing and effective implementation can help to reduce disaster losses by addressing hazards and vulnerability of urban population.

4. Discussion

4.1. Ecosystem based approaches for growing Urban agglomerates

Urban ecosystems are going to be important as contributors to emerging vulnerabilities, threats and also as potential solutions to many environmental challenges Asian cities will face in the coming years. In particular, the loss of agricultural and 'natural' landscapes will place greater pressure on urban green spaces to provide the important ecological, production, and cultural functions that were available from rural areas in the past. An ecological approach for smart development of Nagpur should seriously aim at restoring natural environment of the city to a healthy state while, renouncing upon direct services, tangible and intangible benefits received from these green assets as far as

possible. Yagitcanlar, 2015 [41] has reflected on how ecological approach can facilitate best usage of natural resources for wellbeing of society with minimum impact on environment. Integration of nature in urban areas to improve the quality of life of urban residents is not a new concept as evident in philosophies of pioneer planners in the field of landscape planning and urban ecology, to highlight few are Ian McHarg's "Design with Nature" concept where ecological wisdom was integral part of landscape planning [42,43], Ebenezer Howard's "Garden city concept" representing the blend of city and nature and their dependency on each other [43,44] and Patrick Geddes introduced regional planning theory through his "valley section" [45]. All these philosophies promoted importance of ecology and nature in urban planning post industrial revolution. And recently again the new concept emerged in response to ongoing urbanization pressure on natural assets like landscape urbanism by Charles Waldheim, ecological-urbanism by Mohsen Mostafavi and many more in the field of Urban ecology, Landscape ecology has gained prominence not only in academia but in policy making [46–49]. An examples of landscape urbanism concept is High Line park, through which the abandoned land is transformed into community asset incorporating ecological scientific knowledge, cultural needs in designing to cater to modern requirements [50]. In addition to these new ideas, the key approaches promoting nature and ecology in urban planning to counter climate and disaster related risk are mainly green infrastructure (GI), Ecosystems services (ES) and more recently nature based solution (NbS), ecosystem based disaster risk reduction (EbDRR) and ecosystem based adaptation (EbA). Among all these approaches although GI was relatively old concept with established linkage to urban and landscape planning filed, primarily developed to control urban sprawl by enhancing the ecological network and integrating green space [51,52] however its significance in climate change mitigation and adaptation though multi-functionality is not well explored. Although, the core of concept related to connectivity and multi-functionality [53,54] it is well aligned with ecosystem services provisioning and participatory planning [55]. Ecosystem services concept is widely accepted for nature and biodiversity conservation of natural landscapes and getting prominence in human dominated landscape through increasing research in qualitative and quantitative urban ecosystem assessment aimed to improve quality of life of urban population [56,57]. Although, integration of ES in urban planning for implementation and operationalization still faces many challenges, the concept has helped to understand the associated synergies between ecosystem management and development to support decision making [58]. The nature based solutions (NbS) concept is relatively new and umbrella term introduced by IUCN [59,60] to address global challenges. Although, the scope and definition of the terms are very broad, but the emphasis is on enhancing the resilience of landscapes through innovative solutions considering multi-functionality and building the natural stock against the conventional engineered approach [61]. The EbDRR approach works along the similar line with a focus on risk management against hazards related to both climate on non-climate events. It emphasizes on sustainable management of biodiversity and ecosystems to reduce risk against disasters and enhance resilience and support sustainable development [62] and EbA acts as an overall adaptation strategy for DRR to help adapt people to the impact of climate change and disasters [63,64]. They are both linked in term of their fundamental principal of enhancing resilience of people with a focus on ecosystem management, restoration and conservation [65] and emerged from broader adaptation and DRR practices [66]. Few difference lies in terms of its operation under different policy forums, another one is EbA address only climate related hazard while, Eco-DRR included both climate and non-climate events and come aspect are considered only under Eco-DRR like preparedness and warning systems [67,68].

Convention on Biodiversity supports application and implementation of EbDRR (Decision VII/11). EbDRR programs are fundamental and vital concern for sustainable development. An understanding of linkage or environment-disasters interface are required to incorporate

ecosystem based approaches into development planning. This will help reduce disasters and disaster intensity that aggravates environmental degradation. EbDRR has a lot of potential to be applied as an imperative strategy for reducing emerging urban disaster-risks in urban areas of Nagpur. EbDRR also refereed to be as "no regret approaches" can help in exploiting natural ecosystems and biodiversity developed in the city as buffers to the emerging and/ or extreme events and impacts of extreme environmental threats. The EbDRR concept has stemmed from a long history of using environmental management to adapt to climatic variations and reduce risks from natural hazards. This can help sustain and enhance the resilience of existing and restored natural ecosystems, their ecosystem services and biodiversity that supports them, and help people and communities understand and adapt to ongoing changes. Approach is a tested one by 'sustainable management, conservation and restoration of ecosystems to reduce disaster risks for achieving sustainable and resilient development'. EbDRR will be an efficient tool to put people and their natural resource use practices at the centre of decision making in the city and can help balancing the conservation and use of biological diversity in Nagpur. In present times the approach has become very relevant to professionals and practitioners active in urban planning and management and without the knowledge of EbDRR judicious planning of resilient cities is not possible. EbDRR can help to identify and understand the process of change in ecosystems of Nagpur and enable city planners to plan adaptive strategies for a resilient city of future.

Despite, growing evidence about benefits of ecosystem services and biodiversity provided by nature in the city urban areas of the country struggle to find the required resources and coordination capacities to implement comprehensive vision across the city. Few cities of India may be taken up as good examples for how they have planned their city by keeping greening in mind. Three cities with pioneering positions in the country are Gandhinagar, Chandigarh and Bangalore. Delhi as capital of India has later joined these cities by stimulating greening the city spaces and has emerged as one of the greenest cities of India [69]. The concept of urban ecosystem services can play a crucial function in reconnecting urban spaces to the biosphere. This connection will not only reduce the ecological footprint and ecological debt of growing city but also enhance resilience, wellbeing, and quality of life of their growing urban population. As demands for resources in urban areas have increased drastically, management decisions are replacing self-regulating properties [70,71]. The multiple values of ecosystem services can be captured and identified as significance of these green spaces for the public of Nagpur. But it is very important first to assess and understand the values of these ecosystem services provided by urban green spaces and wetlands. The provisioning ecosystem services provided by urban common property resources in city of Nagpur have always supported the traditional livelihoods of local groups, and subsistence requirements of urban poor, including migrant workers of the city. Cultural ecosystem services comprise recreational benefits and spiritual values attached to the urban natural environment, which in turn support urban inhabitants' social identity [72]. Presence of historical monuments, buildings with heritage value, natural features, forests and sanctuaries are common across the city. The local population of Nagpur finds its roots deeply in the natural environment and greenery of the city and protecting nature is embedded in their culture. This is apparent with the cultural ecosystem services derived from these spaces, for e.g. temples in forested areas on lake banks, or many forested areas, parks and aesthetic sites in city itself [73]. To promote conservation, residents of a village in Maharashtra's Nagpur district have voluntarily relinquished their agricultural land to developed it as 'forest cover' under a unique concept called "community owned nature conservancies" that reflects to the thinking and vision of locals in restoring natural ecosystems.

4.1.1. Ecosystem services

The regulating services of these healthy ecosystems includes

Table 1
Ecosystem services, values and valuation criteria managing ecosystems in Urban areas.

Ecosystem services	Criteria	Probable Valuation methods	Value to property values	Value to urban dwellers in general
Microclimate regulation/reduced heat islands	Saving energy on temperature control of buildings/annum	Assessed in kilowatt hours saved in air conditioning of buildings/year	x	x
Water preservation/harvesting	Gallons of water conserved from run off during flash flood incidents	Assessed in reduction of cost to make civil structures to reduce run off and flash flood situations, amount spent in per gallon water retention	x	x
Soil Conservation	Tons of soil conserved/annum	Assessed in amount spent to enhance nutritional content of soil by application of fertilizers as well as costs invested in controlling leaching	x	
Cultural values and recreational prospects	Landscape quality score/ square foot	Added value to property based on its location, can be assessed in percentage increase in value of the property/square foot, Added value to tickets of these parks and natural forests for morning/evening walk, bird watching, picnics etc	x	xx x
Water Quality	Nutrients added or	Circumvented cost of executing conventional water treatment plan. Assessed in amount required for per MLD of impurities removed or / liter of treated water Reduction in costs of using RO and UV water purifiers at home		x
Air quality	Removed from water or amount spent on water treatment / annum Tons of particulate matter (PM) removed from the atmosphere/annum	Increased value of property, assessed in percentage increase of value land or property/ton/ household of particulate matter (PM) removed from atmosphere	x	x
Carbon sequestration	Carbon dioxide sequestered	Assessed in dollars/ carbon credit (ton carbon) sequestered in voluntary carbon markets		x

increasing sink potential for the city in urban forests and green spaces, reducing air pollution, decelerate rainwater runoff and minimizing flood peaks [74,75]. Therefore, understanding the mechanisms that can link the urban landscape of Nagpur to human and ecological processes is important. This will help to develop strategies, policies and improve resilience from emerging water shortage, floods and increasing temperature situations [76]. Research on the linkages between urban areas, ecosystem services and their potential to reduce urban risks from disasters is still very sporadic in the country. Protecting ecosystems is slowly but strongly reflecting as a vital topic to be integrated as a comprehensive perceptible into ecologically secure urban landscapes of India [77] (Table 1). Table 1 clearly mentions using valuation approach for securing ecosystems, ecosystem services, for managing ecosystems in Urban areas. The criteria is unknowingly used where city locals prefer and pay higher prices to live in natural green surroundings or unpolluted localities. Better quality of life demands better natural surroundings, clean environment and obviously in urban sprawls it is not affordable for many as it comes on a higher price. Approach needs to be streamlined for harnessing the potential of valuation for getting better outcomes of nature conservation, restoration and management in urban areas. Owing to negligence and improper supervision of natural spaces in the city can be clearly understood where the net ecosystem threats and damages (pollution, disease outbreaks, etc.) offsets the better prospects of urban growth [78]. Some of the urban campus forests like one of CSIR-National Environmental Engineering Research Institute (NEERI) spread in 48 ha and Visvesvaraya National Institute of Technology (VNIT) have good green cover this contributes to the micro environment they have created. Urban campus forests are some last remaining islands of protected biodiversity in the cities. They not only provide clean environment but also provide variety of ecosystem services, improve microclimate and give relieve from everyday stress. NEERI campus forests experiences 3° less than the city temperature throughout the year and also acts as a potential carbon sink like many urban forest ecosystems. In present circumstances it is imperative to develop growing urban sprawl of the city to be based on principles of sustainability and ecology [79]. Carbon prices in voluntary markets are dependent on the projects associated with the offset (e.g. reforestation, afforestation etc.) [80,81]. The value per ton of carbon sequestered in managing urban green spaces is expected to be on the lower end of offset costs. The aesthetic and cultural values of urban green spaces can be assessed by their role in improving market value of the property. Studies already reflect that urban dwellers value landscaping within the premises of their property and closeness of their property to urban green spaces and this is also true for Nagpur that is one of the green cities of the country. Urban common green spaces and private gardens and green spaces help to increase the value of property by 2–12% [82,83]. This approach has been found important to strengthen the linkages in smaller landscapes managed well by few urban dwellers in a urban society to the much larger ones often favoured or developed by city planners or municipal corporation. Local governing authorities need to understand the use of natural resources and strategic development and management to sustainably meet the needs of growing urban populations. This includes understanding of urban green spaces, what has been lost in the last few decades, what can be restored and how rapidly? Management of diverse tenurial and institutional arrangements existing in urban green spaces is vital in context of Nagpur as well as other cities. Scaling up the approach through adaptive management needs to be implemented working with multiple stakeholders. Responsibility should not be left only with local or federal government.

4.1.2. Treating waste water

Ecosystem based approaches (that includes benefits of watershed management or protected areas management) have still not been extended to the urban settings, as an important component of urban planning strategies [78]. Watershed management has been an age old

tradition and traditional practices of resource management needs to be revived to manage natural resources in urban spaces. Decentralized wastewater treatment systems are now been considered for peri-urban and urban areas, where sewage network of centralized systems is under developed. Opportunity for wastewater recycle and reuse are now given serious consideration as it can help meeting the growing water requirements of the city. Treated water of Nagpur is supplied to thermal power plant at Koradi, by MAHAGENCO [26]. Water requirement of thermal power plant (about 121 MLD) is now been met by treating sewage of 265MLD. This reduces fresh water usage for the purpose and the company is able to reduce its expenses on water. Phytoid wastewater treatment technology is an effective ecosystem based approach involving variety of plants in constructed wetlands. It is considered for treatment of municipal, urban, agricultural and industrial wastewater. Phytoid technology uses specific plants, such as elephant grass (*Pennisetum purpureum*), cattails (*Typha sp.*), reeds (*Phragmites sp.*), canna and yellow flag iris (*Iris pseudacorus*) that are normally found around natural wetlands and has effective filtration and treatment capability. Phytoid is an excellent example of using nature based solution for tackling waste water challenge in urban areas. Plant based technology has potential to treat urban wastewater while providing alternative livelihood to locals. Treated water quality meets the specified water quality norms of state as well as Central Pollution Control Board (CPCB) (VI fresh water category). Treated water can be reused for gardening, agriculture etc. Technology carried out by onsite treatment and reuse of grey water up to 95%, attracts a total of 5 credits in Indian Green Building Certification (IGBC) [84]. Technology adds value to the building as well as reduces the cost on water requirements in long run. For a city like Nagpur that faces regular water shortage during every summer the ecosystem based approach supported through civil engineering can add to reducing water foot print of the city substantially. Similarly, phytoid technology in combination with rain water harvesting can bring added benefit to the city dwellers. Adding to the monetary benefits rain water harvesting structure waives off 5% on property tax for new constructions as it is now a mandatory requirement for all buildings across many states of India.

4.1.3. River rejuvenation and bank protection

The need has been felt by planners and policy makers for rejuvenation of Nag and Pili river for improving their water quality and protection from further contamination, and encroachment. Chemical and civil engineering solutions are not going to be cost effective solutions in long run to treat waste water, or clean large or small rivers and tributaries of the country. Government is keen on developing, and restoring riparian buffers for major rivers as well as tributaries. Unplanned built up area being a common site on the banks of Nag river, makes it impractical to set a protective buffer area on either side of the river. Development of riverfront can be implemented in two ways. Sections with short width (< 25 m) can have riparian plant buffers on both ends while, sections with width (> 25 m) are to be developed as riverside gardens. Development of gardens, instead of channelization can provide dedicated permeable land area and these can be important recreational spaces too. Maintaining vegetation cover in the city will help stabilizing surface soil, reduce soil erosion, enhance regulating and cultural ecosystem values [85]. National lake conservation plan, a centrally sponsored scheme with 70% share of government of India and 30% from the state government is been implemented to protect lakes of the city by active community participation. Thousands of urban dwellers are coming forward during *Ganpati* festival in last few years to save the city wetlands by active vigilance against thousands of clay and plaster of paris (PoP) idol immersion. This has helped in reducing contamination of lakes and wetlands and enhancing provisioning, regulating and cultural ecosystem services provided by city wetlands and lakes. In a major direction to preserve ecologically crucial wetlands and water bodies threatened by encroachment in many parts of the country, the supreme court of India had directed the central

government to frame a policy to protect wetlands by June 30th of 2017 and in 2017 a strengthened policy to protect lakes and wetlands was drafted. The court's direction is to cover over 2 lakh wetlands across India which were identified through satellite imagery government has been solicit to draw up a phased plan of action to conserve them. These approaches at large and in long run will be of much help. These practices will help reduce the costs of concentration of nutrients in water through engineered methods and also help increased sub surface flow.

4.1.4. Addressing air pollution

Although, ecological planning is gaining importance in the city to reduce air pollution yet the approaches are mainly restricted to urban administrative directions. The implementation of new green highways policy is trying to bridge this gap. The National Forest Policy envisages 33% of the geographical area should be under forest or tree cover, but the notified forest cover is only about 22%. Nagpur city comprises a total length of 38.228 km with 975 km of major roads in and around the city [21]. Green highways (plantation, transplantation, beautification and maintenance) Policy, 2015 provides opportunity for greening of highway corridors by active participation of the community, farmers, private sector, NGOs, and government institutions. About Rs. 1000 crore per year is available for plantation purpose across the country highways that is targeted to fulfil the promises of the country for Paris COP, 2015. Policy intends to generate employment opportunities for about five lakh people from rural areas of the country while, greening the highways. Work has already started in this direction and Nagpur being the focal point the intention to increase green cover and reduce air pollution seems to be adequately addressed.

4.1.5. Afforestation, restoration and biodiversity conservation

Natural resource management strategies should find place in smart city planning as compulsory binding guidelines. This includes green roofs, curb side plantation, and developing vertical gardens. Curbside plantation requires selection of trees and plants in accordance with the width of road available and this is to be achieved with active community participation. Vertical gardens on the sides of pillars of metro corridors as well fly over pillars supporting the girder are pleasant sight that have potential to reduce air pollution affects up to certain extent leading to enhanced regulating ecosystem services. The curb based plantation, plantation below metro route and vertical garden act as green belt lowering effect of vehicular pollution on nearby residential and commercial establishments and if efficiently implemented will help in reducing the intensity of heat islands of the city as well. Rainwater harvesting, green roofs and percentage of every upcoming buildup area are now having mandatory green regulations to follow for urban dwellers across India. Understanding locals' interests, approaches for relevant decisions making, wise choices, can best foster scaling up approaches. Since time immemorial locals of India in general while, Nagpur in particular have always considered the importance of trees, biodiversity, nature and nature-based approaches. Role of ecosystems and empowering multi-stakeholder relationships among residents are to be maintained and even revived by engaging them in long-term commitment for conservation, management and sustainable utilization of urban natural resources.

4.1.6. Benefits and governance

It is pertinent to make appropriate changes and improvements in ecological state of Nagpur by using urban planning strategies, civil engineering approaches, architectural design, and technology, based on ecological concepts and principles [86]. Subsidy or tax benefits in property tax for people implementing green roofs are under consideration of government. It is mandatory to have 33% of green space when any industrial construction happens in any part of the country for environmental clearance of any project under EIA (Environmental Impact Assessment) guidelines, 2016. Ecosystem-based approaches are needed to be replicated and made mandatory for urban buildup areas,

upcoming campus and other infrastructure development projects for supporting and developing actual smart city of Nagpur.

5. Conclusions

The current trends of growing disaster risk in Nagpur in particular and many other Asian cities in general are tough to be abridged, halted, and overturned. Implementing urban land use management progression can only make this happen. This requires recognizing natural and manmade vulnerabilities in urban areas and situations of existing and potential future urban growth patterns. Overall a wise long-term planning that gives due consideration to efficient green civil engineering structures supported by ecosystem based approaches is urgently required. To create smart cities, focus on age old practices of conservation by having right combination of EbDRR, civil engineering approaches and focus on urban ecosystems is warranted. This will help restoring the actual role and function as these urban green and blue spaces that provide vital provisioning, regulatory, cultural, and supporting ecosystem services. This also needs to be comprised of investments to maintain development in a risk-sensitive manner not risk friendly manner. Significant progress towards reduction of situations discussed above and their intensity requires enhanced capacities for EbDRR and approaches that are well integrated in Nagpur smart city development and management plans. At the time when situations of extreme events arises, a secure, aware and empowered urban society can offset with resilience and will be able to cope up with the situations in a better way. The valuation of ecosystem services can support urban decision-making and strategic planning, to reduce costs by conserving energy and improving well-being of local people. Unless, city administrators understand the need to integrate nature's values into decision-making it will not be reflected in significant positive impacts on the environment and quality of life of urban dwellers of Nagpur. Following the Sendai Framework for Disaster Risk Reduction 2015–2030 and Urban SDG 11 Nagpur as well other 100 proposed smart cities need to understand and value the ecological benefits of ecosystems. Awareness generation for protection, restoration, and conservation of urban water bodies has developed sense of belongingness for cultural, regulating and supporting ecosystem values. Support of corporates will help city planners to include efficient and cost-effective technologies to reduce ecological footprint of urban dwellers. Constructed wetlands, wetland buffers and regular cleaning of water bodies in urban areas have a lot of scope for corporate community partnerships. Developing ecologically smart cities in the country is a effective way that government plans for and urban dwellers dream of! The approach has the potential to increase the aesthetic value and resilience of urban sprawls.

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